Design of adaptive 2x2 space-time block codes for broadcasting applications

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M3 Mobile Multi Media

Design of Adaptive 2x2 Space-Time Block Codes for Broadcasting Applications

Motivations

- Future broadcasting systems will call for multi-antenna (MIMO) transmission techniques.
- Space-time block codes (STBC) are conventionally designed according to rank-determinant criteria, efficient at high signal-to-noise ratios (SNR).
- Broadcasting transmissions are protected by powerful forward error correcting (FEC) codes able to operate at low to moderate SNRs.
- **Aim**: design **full-rate full-diversity STBCs** with **low detection complexity,** optimized for **a wide range of SNRs**.

STBC design criteria

- **High SNR**: rank-determinant criteria
  - **Rank criterion**: maximize the rank of $\Delta = \mathbf{X} - \hat{\mathbf{X}}$ for all possible transmitted codeword pairs $(\mathbf{X}, \hat{\mathbf{X}})$
  - **Determinant criterion**: maximize the minimum determinant

$$\delta = \min_{\mathbf{X} \neq \hat{\mathbf{X}}} \prod_{i=1}^{r} \lambda_i$$

  where λ_i are the non-zero eigen values of $\Delta\,\Delta^H$
- **Any SNR**: Bitwise mutual information (BMI) criterion
  - **Maximize**

$$\mathrm{BMI}(c, \hat{c}) = 1 - \mathrm{E}[\log_2(1 + e^{-LLR})]$$

  - The optimized STBC parameters depend on the SNR

  $\Rightarrow$ **construction of adaptive STBCs**

Design of adaptive STBCs

- Example of full-rate full-diversity STBC: the "**Matrix D**" code

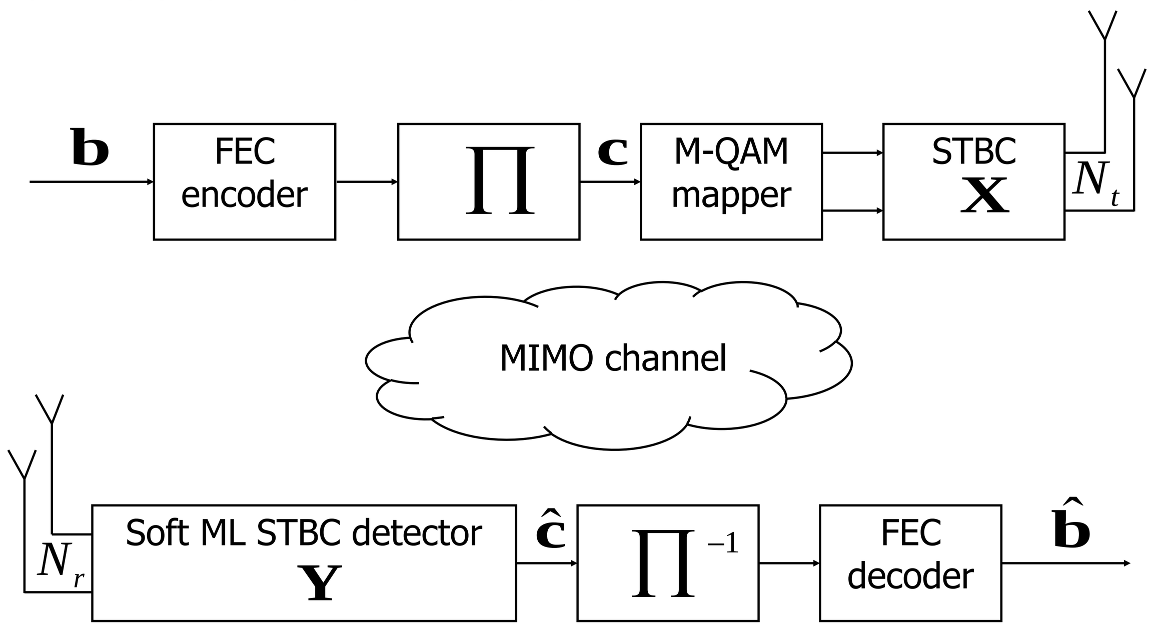
$$\mathbf{X} = \begin{bmatrix} aS_1 + bS_3 & -cS_2^* - dS_4^* \\ aS_2 + bS_4 & cS_1^* + dS_3^* \end{bmatrix}$$

with $a = c = \frac{1}{\sqrt{2}}, d = be^{-i\pi/2}, b = \frac{1}{\sqrt{2}}e^{i\varphi}, \varphi$ being the design parameter

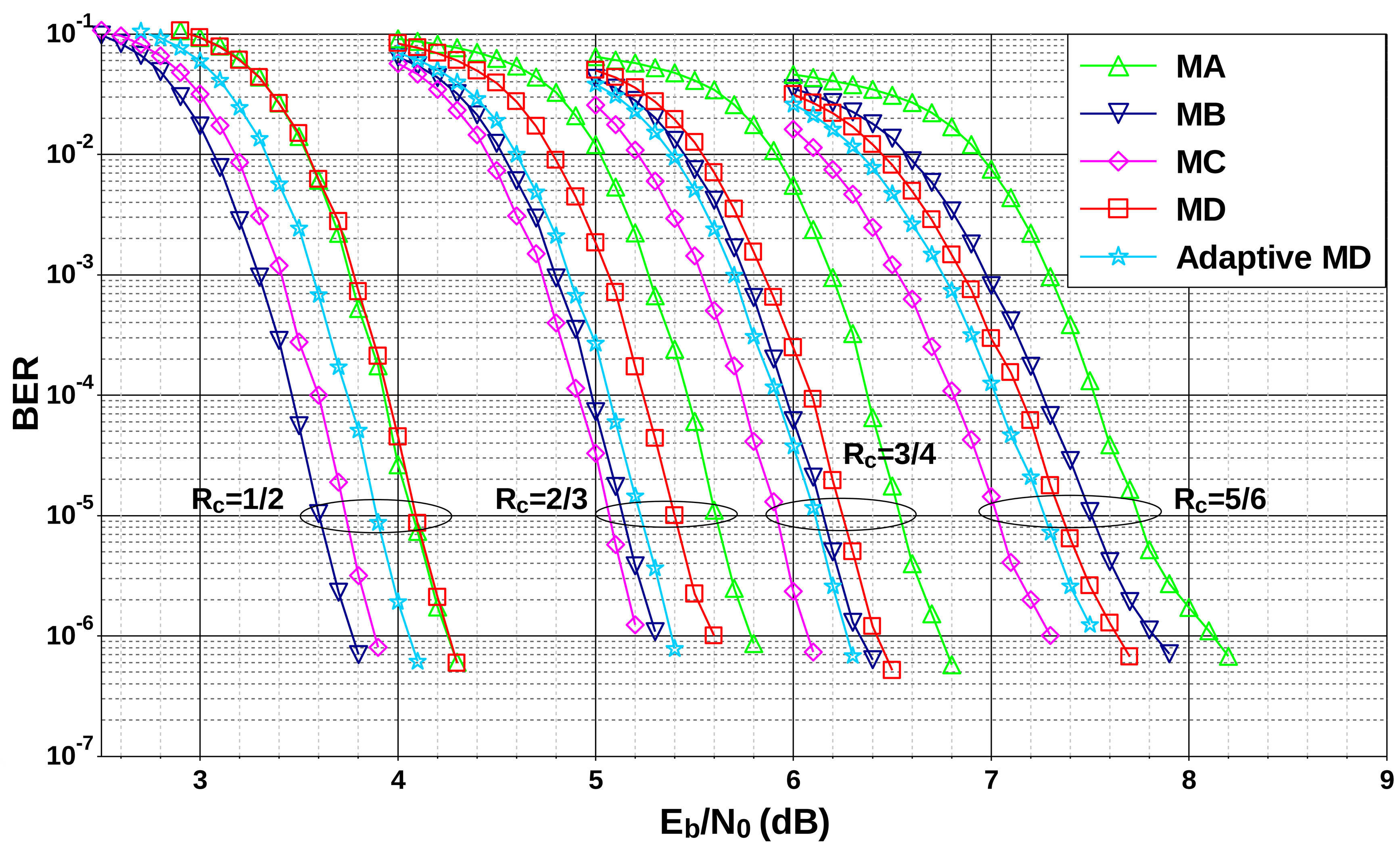
- Rank-determinant criteria (original value): $\varphi = 114.29°$
- BMI criterion: a value of φ is obtained at each SNR
- Based on a polynomial interpolation, φ is given (in degrees) by
- $$\varphi = \begin{cases} 135;\ \text{for } \frac{E_b}{N_0} \leq 5.5\ \text{dB} \\ -0.55\left(\frac{E_b}{N_0}\right)^3 - 14.32\left(\frac{E_b}{N_0}\right)^2 - 123.35\,\frac{E_b}{N_0} + 432.32; \\ \text{for } 5.5\ \text{dB} < \frac{E_b}{N_0} \leq 11\ \text{dB} \\ 114.29;\ \text{for } \frac{E_b}{N_0} > 11\ \text{dB} \end{cases}$$

Performance comparison with state-of-the-art MIMO codes

- **Transmission chain model**



- **Simulation parameters**
  - **FEC code**: WiMAX 8-state double-binary turbo code, coding rates 1/2, 2/3, 3/4, 5/6
  - **Block size**: 4,800 bits
  - **MIMO codes**: MA = Alamouti code, MB = spatial multiplexing, MC = Golden code, MD = original matrix D STBC, Adaptive MD = proposed STBC
  - **Constellation**: 16-QAM for MA and QPSK for MB, MC, MD
  - **Channel**: quasi-static flat Rayleigh fading 2x2 MIMO channel



Maximum likelihood detection complexity per coded bit

MIMO profiles	4-QAM		16-QAM	
	#Add	#Mult	#Add	#Mult
MA/Alamouti	41.5	53	82.75	99
MB/Spatial Multiplexing	84	81	640	641
Adaptive MD and MD	**421**	**510**	**4,096**	**4,257**
MC/Golden Code	1,168	1,284	147,520	163,844

- Adaptive STBC is more efficient than conventional STBC used with powerful FEC coding and/or adaptive modulation and coding (e.g. in broadcasting systems).
- Proposed adaptive MD STBC closes the gap to the Golden code to less than 0.2 dB with approximately 3 times less complexity.
- Adaptive MD STBCs represent a good trade-off between performance and detection complexity.

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